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(54) **THIN FILM TRANSISTOR DISPLAY PANEL
AND MANUFACTURING METHOD
THEREOF**

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USPC 257/59, 72, 258
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,507,991 B2 3/2009 Zhang et al.
8,188,477 B2 * 5/2012 Miyairi et al. 257/59

(Continued)

FOREIGN PATENT DOCUMENTS

JP 2010-004000 1/2010
JP 2010-123932 6/2010

(Continued)

OTHER PUBLICATIONS

Non-final Office Action issued on Dec. 28, 2012, in U.S. Appl. No.
13/172,200.

(Continued)

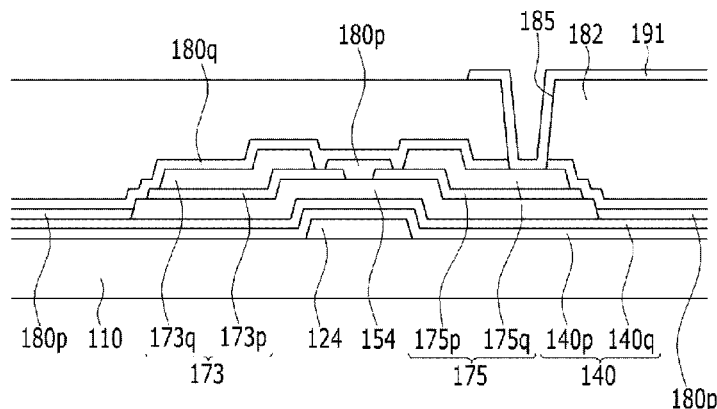
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PLC

(57) **ABSTRACT**

A thin film transistor array panel and a manufacturing method
capable of forming an insulating layer made of different
materials for a portion contacting an oxide semiconductor
and a second portion without an additional process. Source
and drain electrodes of the thin film transistor each include a
lower layer and an upper layer. A first passivation layer con-
tacts the lower layer of the source and drain electrodes but
does not contact the upper layer of the source and drain
electrodes, and a second passivation layer is disposed on the
upper layer of the source and drain electrodes. The first pas-
sivation layer may be made of silicon oxide, and the second
passivation may be made of silicon nitride.

4 Claims, 14 Drawing Sheets



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H01L 29/45 (2006.01)
H01L 29/786 (2006.01)
H01L 23/29 (2006.01)
H01L 23/31 (2006.01)

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CPC **H01L29/41733** (2013.01); **H01L 29/45**
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FOREIGN PATENT DOCUMENTS

JP	2010-243594	10/2010
JP	2010-245118	10/2010
KR	1020100002899	1/2010
KR	1020100040603	4/2010
KR	1020100059586	6/2010
KR	1020100059587	6/2010
KR	1020100070082	6/2010

OTHER PUBLICATIONS

(56) **References Cited**

U.S. PATENT DOCUMENTS

2006/0223210	A1	10/2006	Choi
2007/0087616	A1	4/2007	Sakakura et al.
2009/0032819	A1	2/2009	Lim et al.
2009/0305461	A1	12/2009	Akimoto et al.
2010/0134742	A1	6/2010	Kim et al.
2010/0155719	A1	6/2010	Sakata et al.
2011/0147753	A1 *	6/2011	Onishi et al. 257/59
2011/0193079	A1 *	8/2011	Endo et al. 257/43

Final Office Action issued on May 6, 2013, in U.S. Appl. No. 13/172,200.

Non-Final Office Action issued on Sep. 9, 2013, in U.S. Appl. No. 13/172,200.

Final Office Action issued on Jan. 28, 2014, in U.S. Appl. No. 13/172,200.

Non-final Office Action issued on Apr. 24, 2014, in U.S. Appl. No. 13/172,200.

Notice of Allowance issued on Jul. 18, 2014, in U.S. Appl. No. 13/172,200.

* cited by examiner

FIG. 1

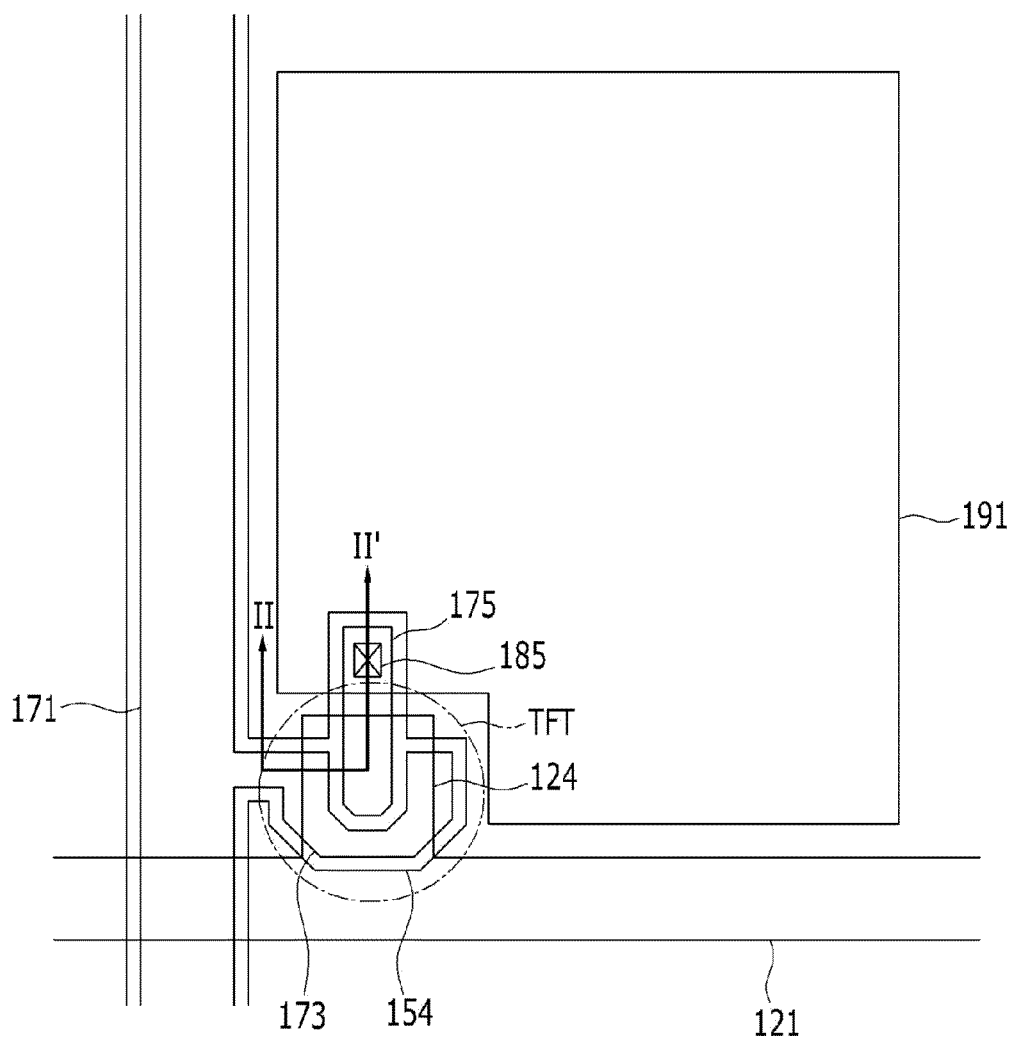


FIG. 2

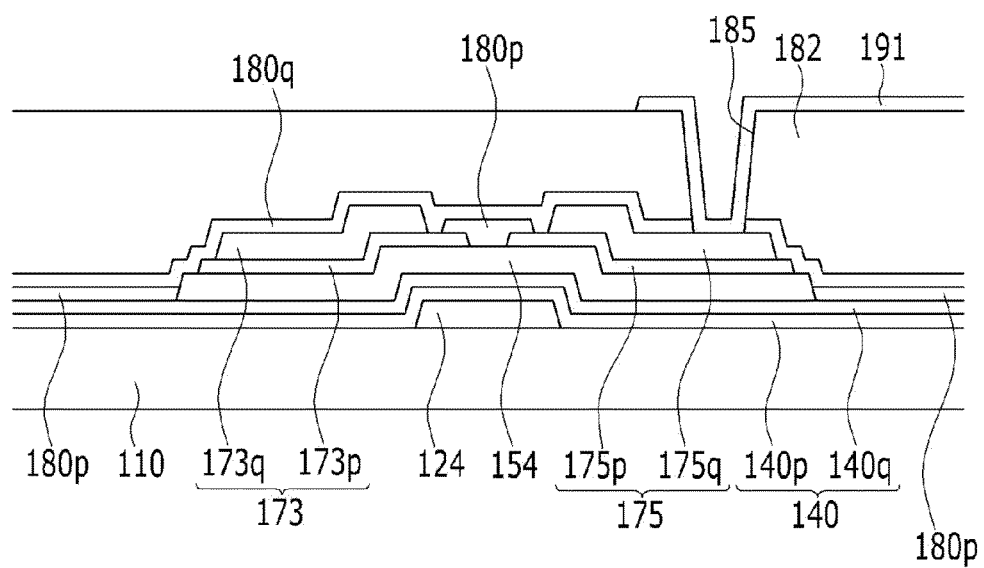


FIG. 3

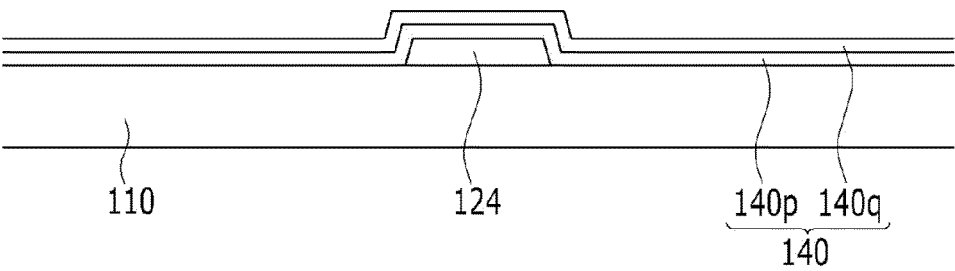


FIG. 4

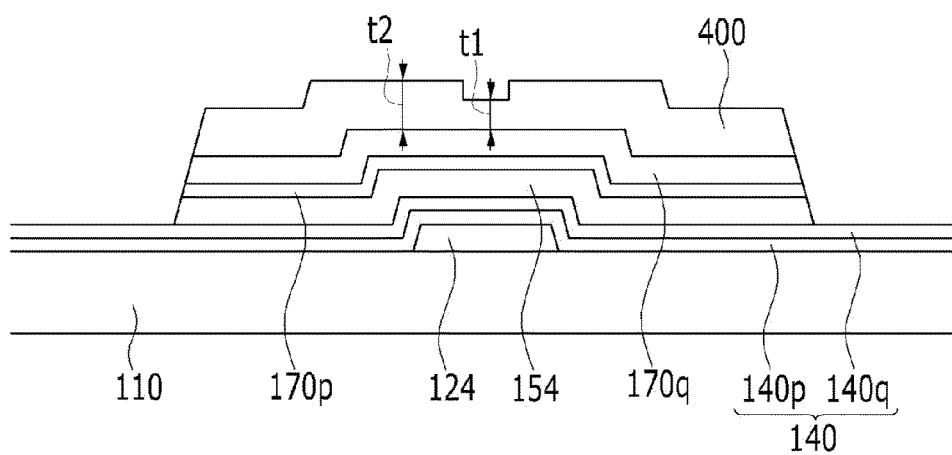


FIG. 6

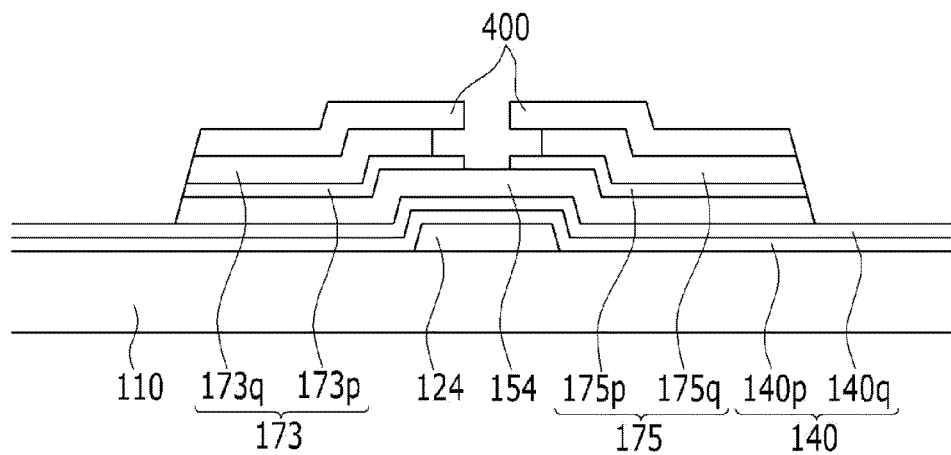


FIG. 7

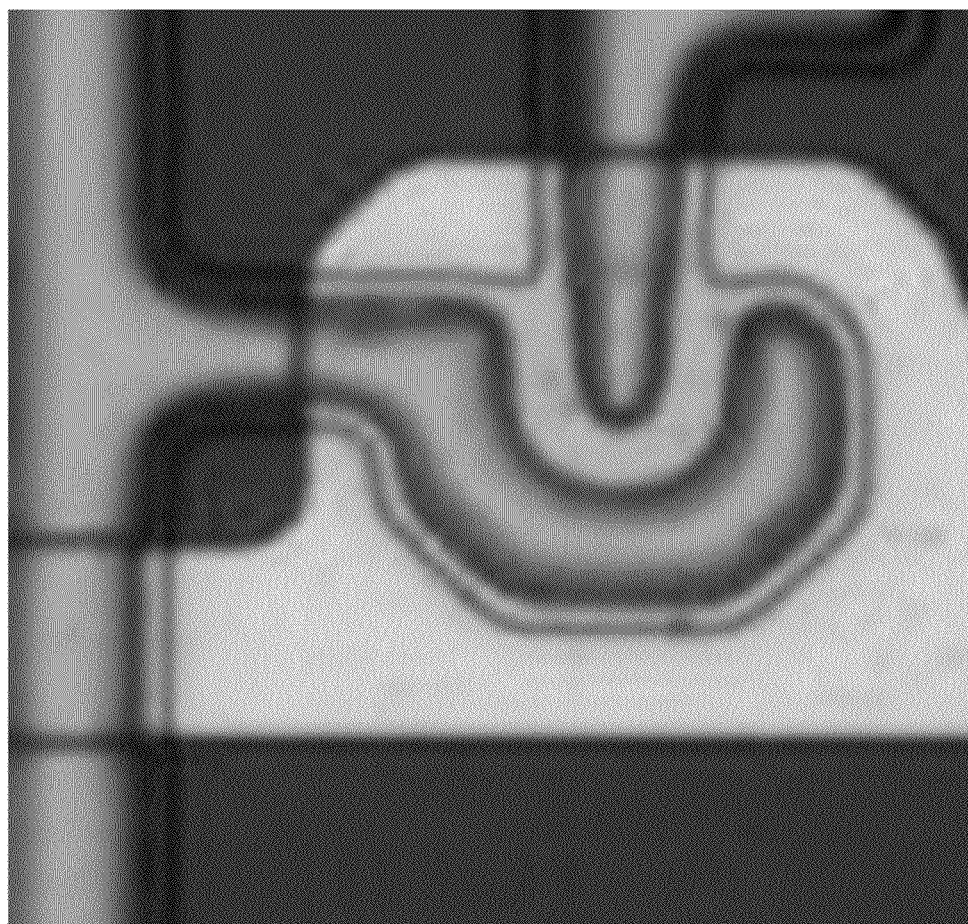


FIG. 8

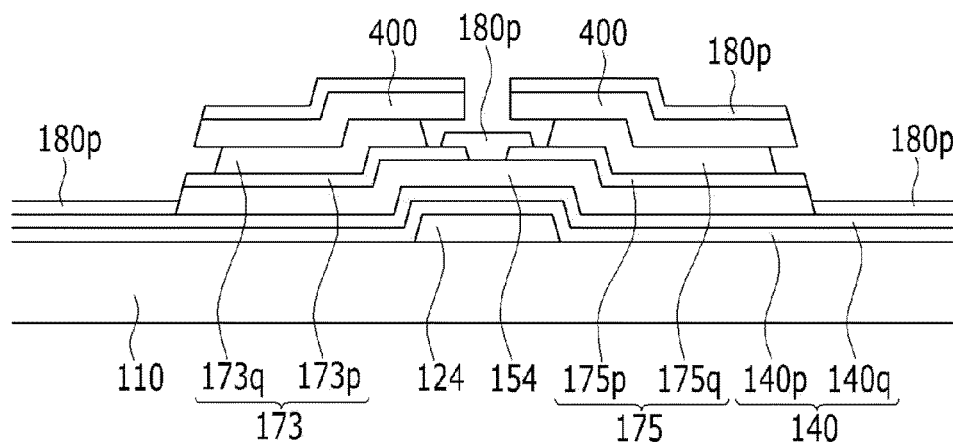


FIG. 9

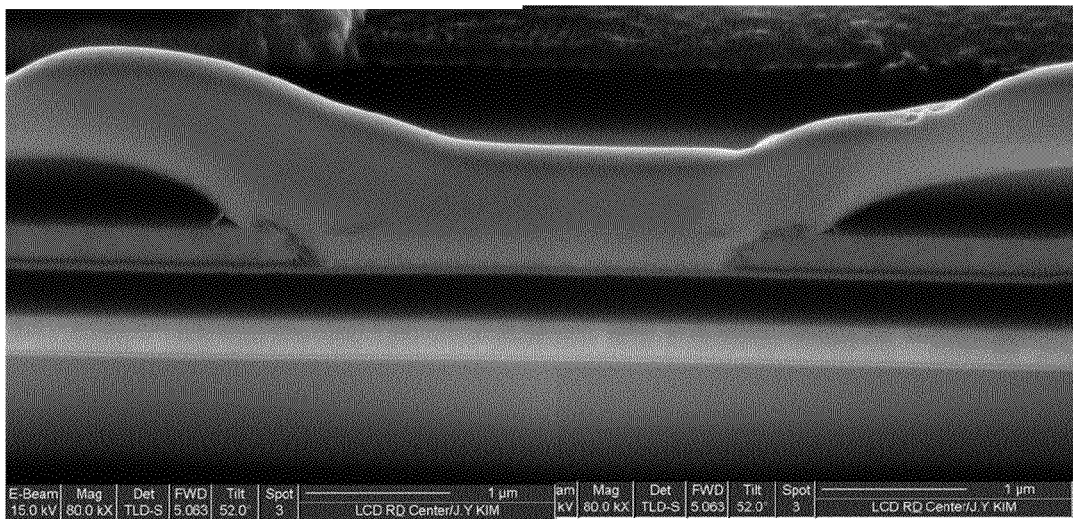


FIG. 10

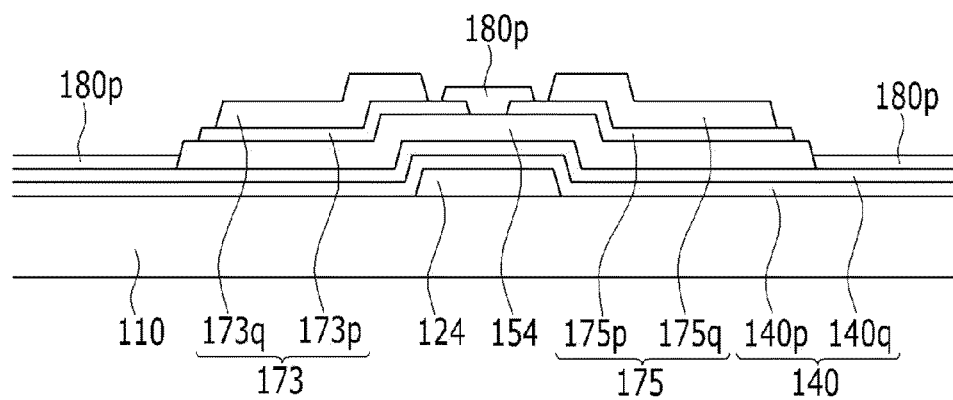


FIG. 11

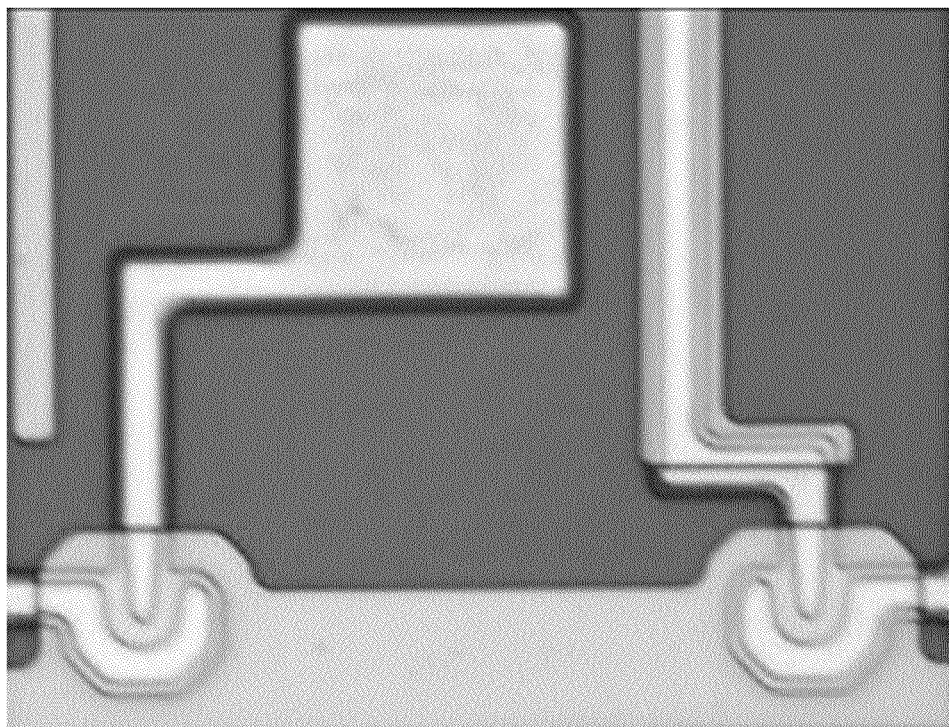


FIG. 12

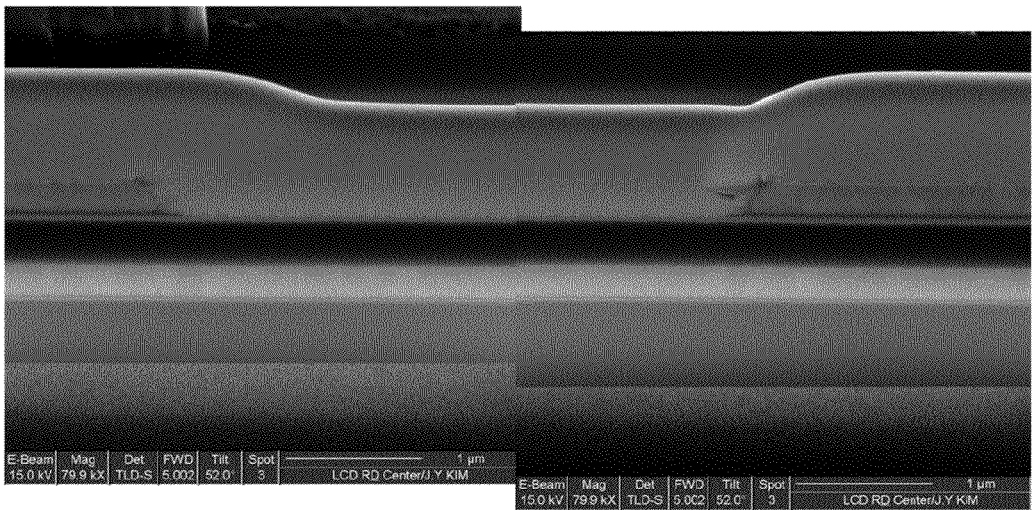


FIG. 13

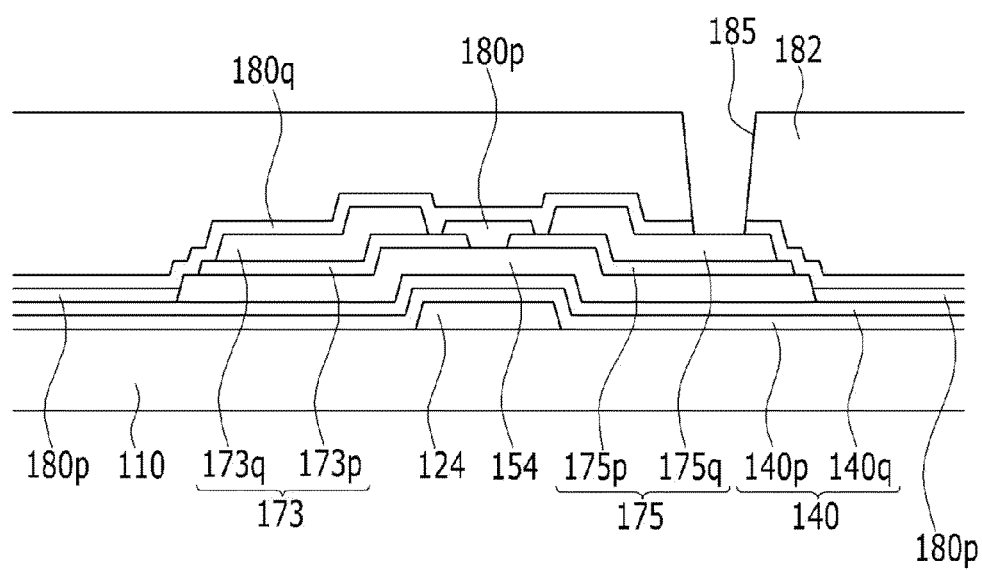
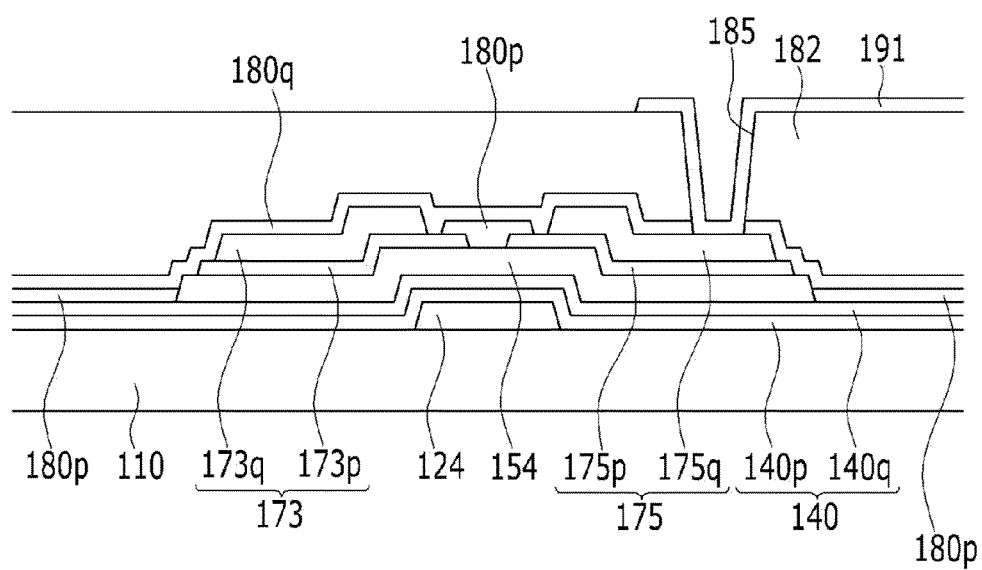


FIG. 14



THIN FILM TRANSISTOR DISPLAY PANEL AND MANUFACTURING METHOD THEREOF

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is divisional of U.S. patent application Ser. No. 13/172,200, filed on Jun. 29, 2011, and claims priority to and the benefit of Korean Patent Application No. 10-2011-0018422, filed on Mar. 2, 2011, each of which is incorporated by reference for all purposes as if fully set forth herein.

BACKGROUND OF THE INVENTION

1. Field

Exemplary embodiments of the present invention relate to a thin film transistor array panel and a manufacturing method thereof. More particularly, exemplary embodiments of the present invention relate to a thin film transistor array panel and a manufacturing method thereof that is capable of forming an insulating layer made of different materials for a portion contacting an oxide semiconductor and the remaining portion without an additional process.

2. Discussion of the Background

A thin film transistor is generally used as a switching element to independently drive each pixel in a flat display device such as a liquid crystal display or an organic light emitting device. A thin film transistor array panel including the thin film transistor includes a scanning signal line (or a gate line) for transmitting a scanning signal to the thin film transistor and a data line for transmitting a data signal, as well as a pixel electrode connected to the thin film transistor.

The thin film transistor includes a gate electrode that is connected to the gate line, a source electrode that is connected to the data line, a drain electrode that is connected to the pixel electrode, and a semiconductor layer that is disposed on the gate electrode between the source electrode and drain electrode, and the data signal is transmitted to the pixel electrode from the data line according to the gate signal from the gate line.

In this case, the semiconductor layer of the thin film transistor includes polysilicon, amorphous silicon, or an oxide semiconductor.

Recently, an oxide semiconductor using a metal oxide having a low cost and high uniformity compared with polycrystalline silicon as well as high charge mobility and a high ON/OFF ratio of current compared with amorphous silicon has been researched.

When forming the semiconductor layer of the thin film transistor by using the oxide semiconductor, if the insulating layer of the portion contacting the oxide semiconductor is made of silicon nitride, the oxide semiconductor may deteriorate due to characteristics of the oxide semiconductor. Also, if the insulating layer contacting the metal layers is formed with silicon oxide, the metal layer may deteriorate.

As described above, when forming the insulating layer by using the same material as the portion contacting the oxide semiconductor and the metal layer, the characteristic of the thin film transistor may deteriorate.

The above information disclosed in this Background section is to enhance the understanding of the background of the invention and therefore it may contain information that does

not form the prior art that is already known in this country to a person of ordinary skill in the art.

SUMMARY OF THE INVENTION

Exemplary embodiments of the present disclosure provide a thin film transistor array panel with an insulating layer comprising silicon oxide contacting an oxide semiconductor and an insulating layer comprising silicon nitride contacting metal layers.

Exemplary embodiments of present invention also provide a manufacturing method for a thin film transistor array panel with an insulating layer comprised of silicon oxide contacting an oxide semiconductor and an insulating layer comprised of silicon nitride contacting metal layers.

Additional features of the invention will be set forth in the description which follows, and in part will be apparent from the description, or may be learned by practice of the invention.

Exemplary embodiments of the present disclosure provide a thin film transistor array panel according to an exemplary embodiment of the present invention includes: a substrate; a gate electrode disposed on the substrate; a gate insulating layer disposed on the gate electrode; a semiconductor disposed on the gate insulating layer; a source electrode and a drain electrode disposed on the semiconductor, the source and drain electrode being spaced apart from each other; a first passivation layer disposed between the source electrode and the drain electrode on the semiconductor and made of silicon oxide; a second passivation layer disposed on the source electrode and the drain electrode and made of silicon nitride; and a pixel electrode connected to the drain electrode.

Exemplary embodiments of the present disclosure provide a method for manufacturing a thin film transistor array panel according to an exemplary embodiment of the present invention includes: forming a gate electrode on a substrate; forming a gate insulating layer on the gate electrode; forming a semiconductor on the gate insulating layer; forming a source electrode and a drain electrode on the semiconductor, the source and drain electrode being spaced apart from each other; forming a first passivation layer comprising silicon oxide between the source electrode and the drain electrode on the semiconductor; forming a second passivation layer comprising silicon nitride on the source electrode, the drain electrode, and the first passivation layer; and forming a pixel electrode connected to the drain electrode.

Exemplary embodiments of the present disclosure provide a thin film transistor including: a gate electrode; a source electrode and a drain electrode spaced apart from each other, each of the source and drain electrodes including a lower layer and an upper layer; an insulating layer disposed between the gate electrode and the source and drain electrodes; a semiconductor, the source electrode and the drain electrode being electrically connected to the semiconductor; a first passivation layer contacting the lower layer of the source and drain electrodes but not contacting the upper layer of the source and drain electrodes; and a second passivation layer disposed on the upper layer of the source and drain electrodes.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are intended to provide further explanation of the invention as claimed. Other features and aspects will be apparent from the following detailed description, the drawings, and the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are included to provide a further understanding of the invention and are incor-

FIG. 14 is a cross-sectional view depicting a manufacturing method for a thin film transistor array panel at an electrode formation step, as taught herein.

It will be understood that when an element or layer is referred to as being "on" or "connected to" another element or layer, it can be directly on or directly connected to the other element or layer, or intervening elements or layers may be present. In contrast, when an element is referred to as being "directly on" or "directly connected to" another element or layer, there are no intervening elements or layers present.

A second passivation layer **180q** is formed on the source electrode **173** and the drain electrode **175**. The second passi-

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vation layer **180q** may be formed on the substrate **110** including directly on the source electrode **173** and the drain electrode **175**. The second passivation layer **180q** may include silicon nitride (SiNx).

An organic insulator **182** may be further formed on the second passivation layer **180q**. The first passivation layer **180p** and the second passivation layer **180q** may be made of an inorganic insulating material such as silicon oxide and silicon nitride. The organic insulator **182** may be thicker than the second passivation layer **180q**, thereby planarizing the substrate **110**.

Here, the organic insulator **182** may be a color filter. In an exemplary embodiment, the thin film transistor array panel includes a plurality of pixel areas, and the color filter may be formed in each pixel area. Also, a light blocking member may be formed at a boundary between the pixel areas.

The second passivation layer **180q** and organic insulator **182** have a contact hole **185** exposing a portion of the drain electrode **175**. A pixel electrode **191** is connected to the drain electrode **175** through the contact hole **185** and is formed on the organic insulator **182**.

In the exemplary embodiment of the present invention, described above, the second gate insulating layer **140q** and the first passivation layer **180p** may be made of silicon oxide. In addition, the first gate insulating layer **140p** and the second passivation layer **180q** may be made of silicon nitride.

A manufacturing method of a thin film transistor array panel according to an exemplary embodiment of the present disclosure will be described as follows with reference to FIGS. 3-14.

FIG. 3 is a cross-sectional view depicting a manufacturing method of a thin film transistor array panel, as taught herein.

Referring to FIG. 3, a gate line (not shown) extending in one direction and a gate electrode **124** protruding from the gate line are formed of a metal material on substrate **110** which is made of glass or plastic.

The first gate insulating layer **140p** is formed on the substrate **110** including the gate line **121** and the gate electrode **124**. In an exemplary embodiment, the gate line **121** and the gate electrode **124** are made by using silicon nitride. The second gate insulating layer **140q** is formed on the first gate insulating layer **140p**. In an exemplary embodiment, the insulating layer **140q** is made by using silicon oxide. Thus, a gate insulating layer **140** which includes first gate insulating layer **140p** and the second gate insulating layer **140q** is formed on the gate line **121** and the gate electrode **124**.

FIG. 4 is a cross-sectional view depicting a manufacturing method of a thin film transistor array panel at a semiconductor and metal deposition step, as taught herein.

As shown in FIG. 4, a semiconductor layer (not shown), a first metal layer (not shown), and a second metal layer (not shown) are sequentially deposited on the gate insulating layer **140**. In exemplary embodiments, the semiconductor layer may be made of an oxide semiconductor such as gallium indium zinc oxide (GIZO), zinc tin oxide (ZTO), and indium tin oxide, or a combination thereof (IZO). The first metal layer may include titanium (Ti), and the second metal layer **170q** may include copper (Cu).

Next, a photosensitive film (not shown) is coated on the second metal layer. The photosensitive film is patterned to form a photosensitive film pattern **400** having two or more thicknesses t1 and t2 through a photolithography process using a mask. Here, the mask used in the photolithography process may be a slit mask or a half-tone mask. The semiconductor layer (not shown), the first metal layer (not shown), and the second metal layer may then be etched using the

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photosensitive film pattern **400** as a mask, thereby forming a semiconductor **154**, a first metal layer **170p**, and a second metal layer **170q**.

FIG. 5 is a cross-sectional view depicting a manufacturing method of a thin film transistor array panel at an etching step, as taught herein.

In FIG. 5, the photosensitive film **400** is ashed to remove the portion of the photosensitive film **400** having the thickness t1. Using the ashed photosensitive film pattern **400**, a portion of the second metal layer **170q** corresponding to the removed portion of the ashed photosensitive film pattern **400** is etched. In an exemplary embodiment, the second metal layer **170q** is formed with copper (Cu) and a wet etching process is applied. Accordingly, a portion of the second metal layer **170q** under the protruding edge of the ashed photosensitive film pattern **400** is also etched.

FIG. 6 is a cross-sectional view depicting a manufacturing method of a thin film transistor array panel at a second etching step, as taught herein.

As shown in FIG. 6, by using the ashed photosensitive film pattern **400** as a mask, a portion of the first metal layer **170p** corresponding to the removed portion of the ashed photosensitive film pattern **400** is etched. In an exemplary embodiment, the first metal layer **170p** includes titanium (Ti) and a dry etching process is applied. Accordingly, in contrast to the etching of the second metal layer **170q**, the first metal layer **170p** is only etched in that portion below the removed portion of ashed photosensitive film pattern **400** in FIG. 5. The portion of the first metal layer **170p** underneath the protruding edges of the ashed photosensitive film pattern **400** is not etched.

The source electrode **173** may be formed to be curved with a substantially "U" shape. The source electrode **173** and the drain electrode **175** are formed by patterning two metal layers such that the source electrode **173** and the drain electrode **175** are formed with lower layers **173p** and **175p** and upper layers **173q** and **175q**, respectively.

The first metal layer **170p** and the second metal layer **170q** are both etched by using the ashed photosensitive film pattern **400**, which has the same shape. However, it will be apparent to those with skill in the art that the first metal layer **170p** and the second metal layer **170q** may have different shapes because of the different etching methods employed for each layer. In an exemplary embodiment, the distance which separates the upper layer **173q** of the source electrode and the upper layer **175q** of the drain electrode is larger than a distance which separates the lower layer **173p** of the source electrode and the lower layer **175p** of the drain electrode. In the exemplary embodiment, the distance between the lower layer **173p** of the source electrode and the lower layer **175p** of the drain electrode is the length of the channel formed in the semiconductor **154**.

FIG. 7 is a photograph of the construction of a thin film transistor array panel as depicted in FIG. 6. Advantageously the process for forming the channel between the source electrode **173** and the drain electrode **175** as described above is executed without deterioration the semiconductor **154** or the metal layers **170p** and **170q**.

FIG. 8 is a cross-sectional view depicting a manufacturing method of a thin film transistor array panel at a first passivation layer formation step, as taught herein.

As shown in FIG. 8, the first passivation layer **180p** is formed on the substrate **110** including the ashed photosensitive film pattern **400**. Thus, the first passivation layer **180p** is formed on the ashed photosensitive film pattern **400**, the second gate insulating layer **140q** and the portion of the semiconductor **154** between the source electrode **173** and the

drain electrode **175**. In an exemplary embodiment, the first passivation layer **180p** may be formed of silicon oxide.

The first passivation layer **180p** covers the exposed semiconductor **154** between the source electrode **173** and the drain electrode **175**. In an exemplary embodiment, the first passivation layer **180p** overlaps the edges of the lower layers **173p** and **175p** of the source electrode and the drain electrode such that the semiconductor **154** may be prevented from being exposed to the atmosphere at the edges of the lower layer **173p** of the source electrode and the lower layer **175p** of the drain electrode.

FIG. **9** is a cross-sectional photograph depicting an exemplary thin film transistor array panel manufactured as depicted in FIG. **8**. As those with skill in the art will understand, FIG. **9** confirms that the first passivation layer **180p** may be formed on the edges of the lower layers **173p** and **175p** of the source electrode and the drain electrode.

FIG. **10** is a cross-sectional view depicting a manufacturing method for a thin film transistor array panel at a first passivation layer partial removal step, as taught herein.

As shown in FIG. **10**, the ashed photosensitive film pattern **400** is removed through a lift-off process. The first passivation layer **180p** formed on the ashed photosensitive film pattern **400** is also removed therewith. Thus, the first passivation layer **180p** remains between the source electrode **173** and the drain electrode **175** on the semiconductor **154** and on the second gate insulating layer **140q**, but is not on the upper layer **175q** of the drain electrode and the upper layer **173q** of the source electrode.

FIG. **11** is a cross-sectional photograph depicting an exemplary thin film transistor array panel manufactured as depicted in FIG. **10**. FIG. **12** is a plane photograph depicting an exemplary thin film transistor array panel manufactured as depicted in FIG. **10**. As those with skill in the art will understand, FIGS. **11** and **12** confirm that the first passivation layer **180p** may be removed along with the ashed photosensitive film pattern **400** through the lift-off process described in relation to FIG. **10**.

FIG. **13** is a cross-sectional view depicting a manufacturing method for a thin film transistor array panel at a second passivation layer formation step, as taught herein.

As shown in FIG. **13**, the second passivation layer **180q** is formed on the surface of the substrate **110** including the source electrode **173**, the drain electrode **175** and the first passivation layer **180p**. The second passivation layer **180q** may include silicon nitride.

Next, an organic insulator **182** made of the organic insulating material is formed on the second passivation layer **180q**, thereby planarizing the substrate **110**. In an exemplary embodiment, the organic insulator **182** may be made of a color filter. The thin film transistor array panel includes a plurality of pixel areas, and a color filter may be formed in each pixel area. Also, a light blocking member may be formed at a boundary between the pixel areas.

Next, the organic insulator **182** and the second passivation layer **180q** are patterned to form a contact hole **185** exposing a portion of the drain electrode **175**.

FIG. **14** is a cross-sectional view depicting a manufacturing method for a thin film transistor array panel at an electrode formation step, as taught herein.

As shown in FIG. **14**, a transparent electrode is formed on the organic insulator **182** and patterned to form a pixel electrode **191**. The pixel electrode **191** is connected to the drain electrode **175** through the contact hole **185**.

In the manufacturing method of the thin film transistor array panel according to an exemplary embodiment of the present disclosure, four masks are used to form the thin film

transistor array panel. The photolithography process uses the first mask to form the gate electrode **124**. The second mask is used to form the semiconductor **154**, the source electrode **173**, the drain electrode **175** and the first passivation layer **180p**. The photolithography process uses the third mask to form the contact hole **185** in the second passivation layer **180q** and the organic insulator **182**. The fourth mask is used to form the pixel electrode **191**. Advantageously, the manufacturing of the thin film transistor array panel using a total of four masks does not increase the time and costs of the photolithography progress in comparison to conventional manufacturing processes.

In an exemplary embodiment of the manufacturing method of the thin film transistor array panel, the second gate insulating layer **140q** and the first passivation layer **180p** may be made of silicon oxide. The first gate insulating layer **140p** and the second passivation layer **180q**, may be made of silicon nitride. Advantageously, in the exemplary manufacturing method of the thin film transistor array panel, the insulating layer contacting the semiconductor **154** (i.e. first passivation layer **180p**) and the insulating layer contacting the metal layers **170p** and **170q** (i.e. the second passivation layer **180q**) may be formed with different materials without the need for an additional photolithography process.

Although the exemplary embodiment of FIG. **2** includes a bottom gate thin film transistor, other thin film transistor structures are possible. For example, the thin film transistor may be a top gate thin film transistor, where the gate electrode is disposed above the source and drain electrodes in relation to the substrate.

It will be apparent to those skilled in the art that various modifications and variation can be made in the present invention without departing from the spirit or scope of the invention. Thus, it is intended that the present invention cover the modifications and variations of this invention provided they come within the scope of the appended claims and their equivalents.

What is claimed is:

1. A thin film transistor, comprising:

- a gate electrode;
 - a source electrode and a drain electrode spaced apart from each other, each of the source and drain electrodes comprising a lower layer and an upper layer;
 - an insulating layer disposed between the gate electrode and the source and drain electrodes;
 - a semiconductor, the source electrode and the drain electrode being electrically connected to the semiconductor;
 - a first passivation layer contacting the lower layer of each of the source and drain electrodes but not contacting the upper layer of each of the source and drain electrodes; and
 - a second passivation layer disposed on the upper layer of each of the source and drain electrodes,
- wherein the second passivation layer directly contacts an upper surface of the lower layer of each of the source and drain electrodes.

2. The thin film transistor of claim 1, wherein the first passivation layer is disposed between the source electrode and the drain electrode and also contacts the semiconductor.

3. The thin film transistor of claim 2, wherein the second passivation layer contacts the first passivation layer and the upper layer of the source and drain electrodes.

4. The thin film transistor of claim 1, wherein the first passivation comprises silicon oxide, and the second passivation layer comprises silicon nitride.